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PENSOFT.

Triuris hyalina Miers: first record of Triuridaceae in the southern Atlantic Forest of Paraná, Brazil

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Abstract

We report the first occurrence of the family Triuridaceae in the Atlantic Forest of Paraná state, Brazil. We found *Triuris hyalina* Miers in a nature reserve and present a description, taxonomic and ecological comments, distribution data, and images. It is a small, mycoheterotrophic plant species. We found it in an area of dense ombrophilous forest in the municipality of Piraquara, eastern Paraná. Our new record represents the first of the family in the state and the southernmost known occurrence of the species. The new occurrence highlights the importance of floristic surveys to better understand the flora of the Atlantic Forest.

Keywords

Dense ombrophilous forest, geographic distribution, mixed ombrophilous forest, mycoheterotrophic plant, new occurrence

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Introduction

The family Triuridaceae Gardner is a group of fully mycoheterotrophic plants that grow in deep shade in the understory of wet forests worldwide in the tropics and subtropics (Suetsugu 2018; Maas and Maas 2005). Completely mycoheterotrophic plants do not perform photosynthesis but instead use fungi as their carbon source (Merckx 2013; Gomes et al. 2020). The family Triuridaceae consists of nine genera and 55 species (APG 2016) of achlorophyllous herbs, which are up to 10–15 cm tall and have reduced scale-like leaves. They normally grow in humid habitats, often under deep forest cover in humus-rich soils (Rudall 2003). Because Triuridaceae are small, inconspicuous, and ephemeral plants, relatively few collections have been made, and their systematics and biology remain relatively poorly understood (Rudall 2003; Gomes et al. 2019). Recent molecular phylogenetic studies have shown that the Triuridaceae constitute a single clade within Pandanales (Mennes et al. 2013; Suetsugu et al. 2017; APG 2016). The Brazilian Atlantic Forest region is home to a high diversity of mycoheterotrophic plants, many of which are endemics such as *Lacandonia brasiliana* A. Melo & M. Alves, *Peltophyllum caudatum* (Poulsen) R. Schmid & M.D. Turner, *Triuris alata* Brade, from the family Triuridaceae, and *Voyria*

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obconica Progel from the family Gentianaceae (Merckx et al. 2013).

In Brazil, five genera belonging to Triuridaceae have been reported: *Peltophyllum* Gardner, *Sciaphila* Blume, *Soridium* Miers, *Lacandonia* E. Martinez & Ramos, and *Triuris* Miers (Vilela-Santos et al. 2013; Flora do Brasil 2020). Triuridaceae is represented by 13 species in Brazil, and the greatest species diversity is found in the Atlantic Forest, with four genera and seven species, followed by the Amazon region with three genera and eight species. The species recorded in the Atlantic Forest are *Lacandonia brasiliensis* A. Melo & M. Alves, *Peltophyllum caudatum*, *Petophyllum luteum* Gardner, *Sciaphila purpurea* Benth., *Sciaphila schwackeana* Johow, *Triuris alata*, and *T. hyalina* Miers. The only species that has been recorded in southern Brazil is *S. schwackeana*, with a single individual collected by the botanist Ule in 1887 in Itajaí, Santa Catarina state (Maas et al. 2015).

Triuris is a genus consisting of three species distributed from southern Mexico to southern Brazil (Maas and Maas 2005) (Fig.1), which are characterized by mostly single (occasionally two or three) mushroom-like, whitish flowers at the end of a leafless, hyaline stem (Vilela-Santos et al. 2013). The individual floral unit consists of unisexual structures borne on a racemose inflorescence. The perianth in female flowers has three triangular tepals arranged in a single cycle and is basally connate, each one ending in a short, caudate apex (Espinosa-Matías et al. 2012). The gynoecia are apocarpous, with a variable number of carpels, subapical style on the ovary, and no differential stigma (Fig. 2 G). One of the most significant characteristics common to mycoheterotrophic plants is the extreme reduction of the size of their seeds, which are usually dispersed by wind (Leake 1994; Erikson and Kainulainen 2011). However, the structure of diaspores in these species differs from that of typical anemochorous seeds, those that have wings and are very light as in *Voyria aphylla* (Jacq.) Pers. and *Wullschlaegelia aphylla* (Sw.) Rchb.f., as they are longer and possess a reticulate epidermal pattern on their fruitlet wall (Suetsugu et al. 2017) (Fig. 2G). The dispersal units are achenes, and the fruit development is asynchronous and centrifugal. Achenes placed at the receptacle center are the earliest to ripen and also dispersed first (Fig. 2 F). Only two species belonging to the genus occur in Brazil, both of which are restricted to the Atlantic Forest biome: *T. alata* Brade (Rio de Janeiro) and *T. hyalina* Miers. Both of these species occur in the states of Amazonas, Espírito Santo, Rio de Janeiro, and São Paulo (Maas and Maas 2010). In this study, 20 individuals of *T. hyalina* were collected, marking the first records of Triuridaceae in state of Paraná, Brazil.

Methods

The data were collected from May 2019 to March 2021 in a locality with vegetation typical of a dense ombrophilous forest with mixed ombrophilous forest in western Paraná (IBGE 2012). Individuals of *T. hyalina* were collected in a permanent sampling plot in the Piraquara forest, where 50 permanent plots of 40 m^2 and over six parallel transects 100 m apart were allocated. The municipality of Piraquara, Paraná, has a wet climate, Cfb, according to the Köppen climate classification system (Sparovek et al. 2007)

Our study was carried out in the southern Atlantic Forest as part of the research project entitled "Mycoheterotrophic plants of Curitiba and Piraquara". We collected 20 individuals of Triuridaceae on the plots and surrounding a water body. The specimens were all identified as *T. hyalina*, and the samples were taken to the Forest Ecology Laboratory of the Center for Forestry and Wood Sciences, the Federal University of Paraná (CIFLOMA, UFPR). A Leica DMS300 digital

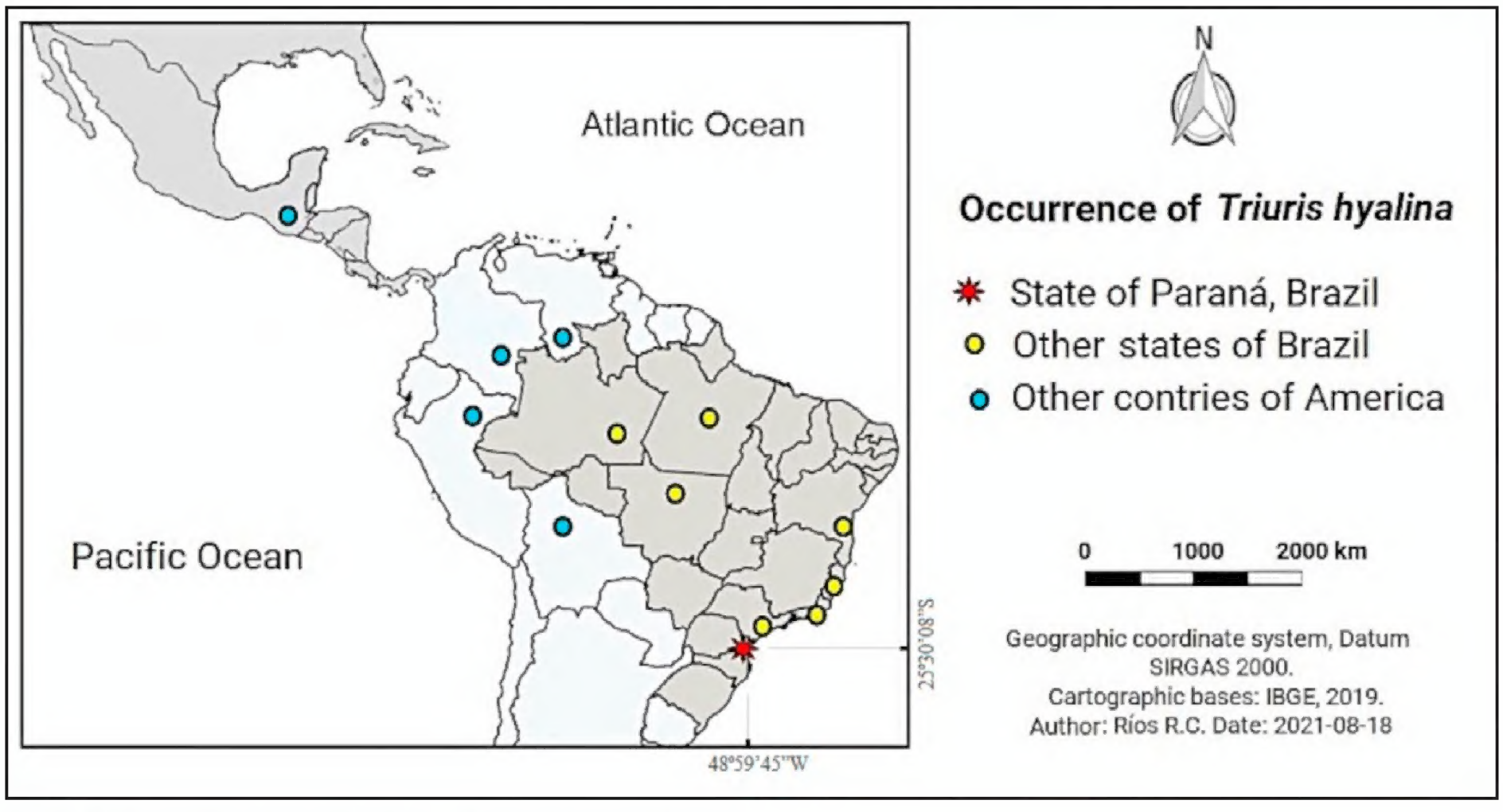

Figure 1. Occurrence of *Triuris hyalina* on the American continent.

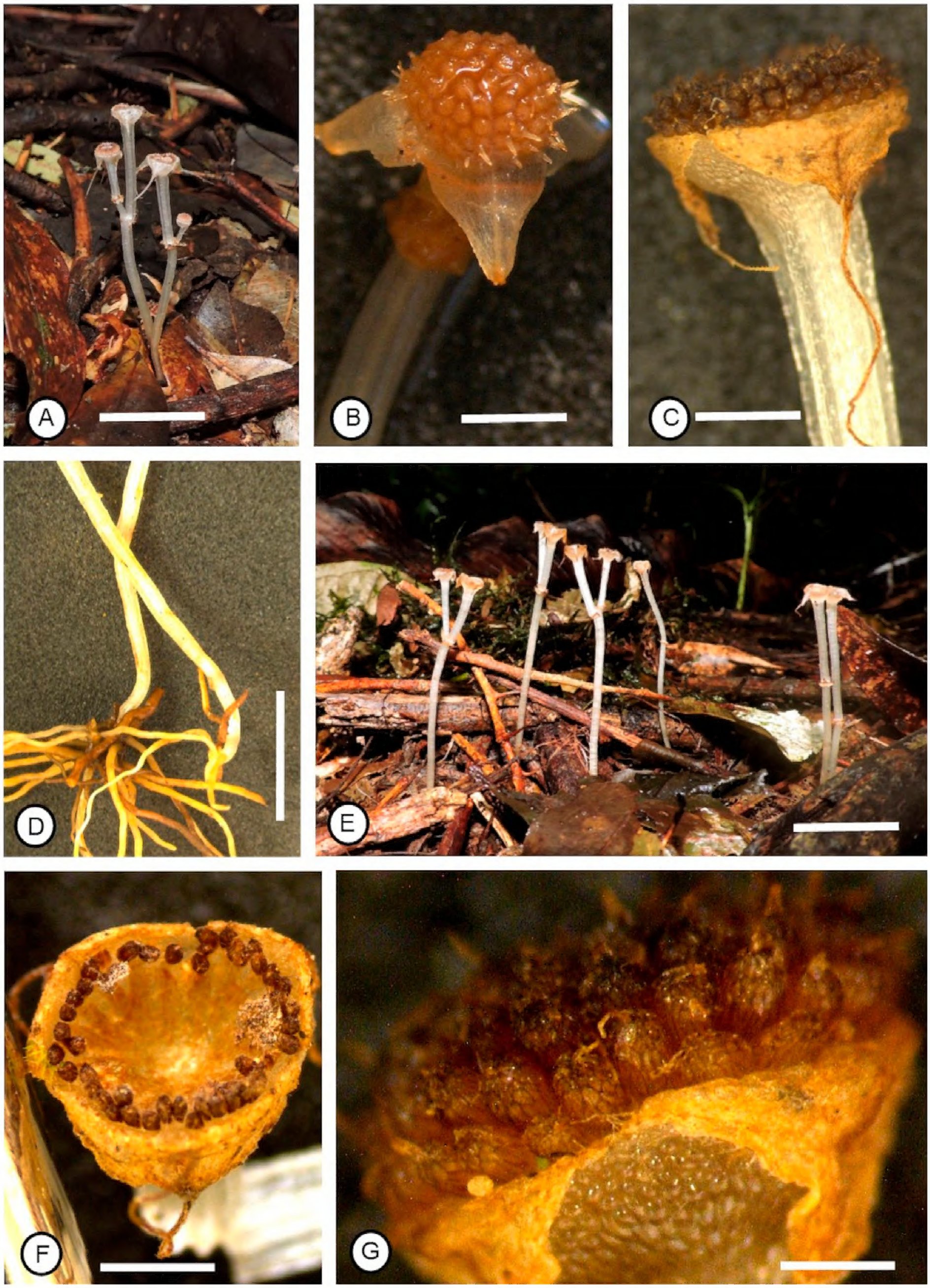

Figure 2. *Triuris hyalina.* **A–E.** Habit and female flowers. **B.** Female flower with apocarpous gynoecium. **C.** Hyaline stem with receptacle, tepals and ripe achenes ready for dispersion. **D.** Habit with roots and stems. **F.** Receptacle showing last ripe fruits. **G.** Achenes with reticulate pericarp and persistent style. Scale bars: A, D = 2.5 cm; B, C = 2.5 mm; F = 2 mm; G = 1 mm.

microscope system with 8:1 zoom optics combined with a 2.5 MP digital camera at a magnification of up to 300× was used to study and photograph the collected material. Specialist literature was used to confirm the identity of the specimens (Maas and Rübsamen, 1986; Espinosa-Matías et al. 2012; Vilela-Santos et al. 2013; Govaerts 2017). Morphological terminology follows Gonçalves and Lorenzi (2011). The material was deposited in the Curitiba Forest School Herbarium (EFC), CIFLOMA, UFPR (Thiers 2016). Classification of vegetation follows the Brazilian Vegetation Technical Manual (IBGE 2012).

Results

Triuris hyalina **Miers**, Trans. Linn. Soc. London, 19: 79 (Miers 1845), fig.19. (Maas and Rübsamen 1986)

New record. BRAZIL – **Paraná** • Piraquara, Mananciais da Serra; 25°30′08″S, 048°59′45″W; 980 m elev.; 01.V. 2019; R.C. Ríos and V.J.M.V. Cruz 001 leg.; EFC 18168.

The specimens were all identified as *T. hyalina* and represent the first times that *T. hyalina* has been collected in Paraná.

Triuris hyalina is a mycoheterotrophic plant without chlorophyll, less than 16 cm tall, and with a hyalina pedicel and terminal raceme inflorescence. Its small size and the vegetative organs of all species of Triuridaceae are associated with their mycoheterotrophy (Rudall 2008; Espinosa-Matías et al. 2012).

Triuris species are generally described as having dioecious reproduction (Maas and Rübsamen 1986). However, morphogenetic studies of *T. hyalina* and *Lacandonia schismatica* from Mexico has revealed some hermaphroditic flowers among male and female flowers in the same individual plant (Vergara-Silva et al. 2003). Espinosa-Matías et al. (2012) proposed the term polygamodioecious to describe the complexity of the reproductive system of *T. hyalina*. However, in 10 years of field collections, Espinosa-Matías et al. found few male individuals and very few hermaphroditic individuals. In our two years of field collections, we have only encountered female individuals; neither male flowers nor monoicous individuals were found. *Triuris hyalina* was recorded in moist leaf litter from a preserved area of an ecotone between an ombrophilous dense forest and an ombrophilous mixed forest and in a forest under secondary succession with 50 years of recovery since the last disturbance.

There are no data on the dispersal of *T. hyalina*. Zoochory (specifically myrmecochory, or dispersal by ants) has been identified as a dispersal mechanism in other Triuridaceae species (Suetsugu et al. 2017). Dispersal by raindrops (ombrohydrochory) has been cited for species of Thismiaceae with fruits whose external morphology is similar to that of *T. hyalina* (Peres-Coelho et al. 2021).

We have found *T. hyalina* co-occurring with other mycoheterotrophic species like *Apteria aphylla* (Nutt.) Barnhart ex Small and *Gymnosiphon tenellus* (Benth.) Urb (Burmanniaceae), and *Voyria aphylla* (Gentianaceae). Triuridaceae are very inconspicuous, and it is extremely hard to discover them in the deep shade of the forest floor (Fig. 2E).

Description. Myco-heterotrophic herb 5–16 cm high, white throughout, roots glabrous to sparsely hairy (Fig. 2A, D, E). Inflorescence a 1–4 -flowered raceme. Plant dioecious, unisexual flower. Female flower has three triangular tepals arranged in a single cycle and is basally connate, 1.5–3 mm long, apex with a tail-like appendage 4–13 mm long. Carpels many, style terminal. The style is topographically subapical on the ovary and there is no differentiated stigma. Fruit consisting of many free, indehiscent fruitlets (achenes), 0.5–1 mm long. Fruit development is asynchronous and centrifugal. Achenes placed at the center of the receptacle are the earliest to ripen. Seeds globose to ellipsoidal, pericarp appears reticulate (Fig. 2C, F, G).

Distribution. Rain forest of southern Mexico, non-inundated forest of Amazonian regions of Venezuela, Colombia, Peru, Bolivia, and Brazil. In the Brazil, it is known from the states of Mato Grosso (GBIF 2021), Espírito Santo, Rio de Janeiro, São Paulo (Maas et al. 2015), and now Paraná. *Triuris* has a disjunct distribution with large empty areas between collection sites, reflecting insufficient sampling in the Neotropics (Merckx et al. 2013) (Fig. 1).

Key to differentiating the mycoheterotrophic plant families of Paraná

1 Pentamerous flowers . . . . . Gentianaceae Juss.
1′ Trimerous flowers
  2 Zygomorphic flowers
    3 Flowers gathered in inflorescences . . . . . Orchidaceae A.Juss.
    3′ Flowers single . . . . . Thismiaceae J. Agardh
  2′ Actinomorphic flowers
    4 Apocarpic carpels . . . . Triuridaceae Gardner
    4′ Sincarpic carpels . . . . Burmanniaceae Blume

Discussion

The new record of Triuridaceae and *Triuris hyalina* from Paraná extends the geographic range of the family and species toward the southern extent of the Atlantic Forest. Two species of *Triuris* are present in Brazil, *T. alata*, which is endemic to the Atlantic Forest, and *T. hyalina*. *Triuris alata* has only been recorded since 1942 in the wet forest of Rio de Janeiro state (Brade 1943). This species can be distinguished from *T. hyalina* by its larger size and conspicuous rhizome, while *T. hyalina* has a very small or absent rhizome. Three other mycoheterotrophic species have been recorded in the same area: *A. aphylla*, *G. tenellus*, and *V. aphylla*. Some authors have mentioned the co-occurrence of several mycoheterotrophic families and species at individual sites (Maas and Rübsamen 1986; Merckx et al. 2013). The most accepted cause for the co-occurrence of mycoheterotrophic plants

is their preference for similar microhabitat conditions. These microhabitats are characterized by humidity, soil type, and leaf litter depth (Merckx et al. 2013). According to Gomes et al. (2019), moisture is explanation for the co-occurrence of mycoheterotrophic plants and edaphic factors are more important to explain the local distribution of individuals. The almost exclusive occurrence in humid forests may be the result of competitive advantages over other plants that grow in low -light conditions.

The largest tree species recorded in our study area are at their intermediate stages of life and have diameters up to 50 cm. The characteristic tree species present were *Laplacea fruticosa* (Schrad.) Kobuski, *Cedrela fissilis* Vell., *Psichotria vellosiana* Benth., *Styrax leprosus* Hook. & Arn., and *Ocotea puberula* (Rich.) Nees, all of which reached heights of up to 15 m. Numerous springs are found over the property, and these form small, swampy areas which are conducive to mycoheterotrophic plants. Old growth forest trees in this region can reach 30 m in height and 150 cm in diameter (IBGE 2012).

Our study demonstrates the importance of floristic studies in remnants of the Atlantic Forest, the most threatened biome in Brazil (SOS Mata Atlantica 2021), where habitat fragments tend to be isolated within conservation units. This study also demonstrates that forests in an advanced state of succession support the existence of mycorrhizal fungi—without which mycoheterotrophic species would not exist—and are therefore similar to the old-growth forests.

New species of Thismiaceae are constantly being described (i.e., *Thismia ribeiroi* Engels, D. Ferreira-da-Silva & Soares-Lopes 2020), as the group has long remained elusive to researchers due to the inconspicuousness of mycoheterotrophic plants (Merckx et al. 2013; Ferreira da Silva et al. 2020). The group of mycoheterotrophic plants remains particularly poorly studied in the Atlantic Forest. The region's topology, consisting of escarpments and many springs and rivers, makes the southern Atlantic Forest very promising for more discoveries.

The abundance and ecology of most species of mycoheterotrophic plants remain poorly understood, and only long-term research will elucidate the extent, diversity, and ecology of this group. The first record of *T. hyalina* in southern Brazil and Paraná state expands our knowledge about this mycoheterotrophic plant species' geographic distribution and environmental requirements. It is paramount to expand collection areas outside the well-known or more frequented places to discover new species and determine geographic distributions of already known species. Greater collection effort at each sampling area are also necessary, as flowering and fruiting are very short in duration and poorly known. As Martín-Lopez et al. (2007) argued, new distributional records are essential to understanding true geographic ranges of species. In view of current rates of biodiversity loss, it is essential to raise public awareness of the value of biodiversity and include less noticeable and attractive species.

Most mycoheterotrophic species prefer well-preserved forest areas (Gomes et al. 2019) where thick leaf litter offers optimal conditions for mycorrhizal fungi. Continuous circulation of people and domestic animals in disturbed forest fragments alters the structure of the leaf litter and compacts the upper soil and litter layers. Mycoheterotrophic plants can act as bioindicators (Melo et al. 2010; Valadares et al. 2015; Farías-Pinheiro 2020) and may have a prominent position when designing conservation units and formulating management plans.

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Authors' Contributions

Concepualization: RCR. Data curation: RCR. Formal analysis: RCR. Investigation: RCR, VJMVC. Methodology: RCR. Validation: VJMVC. Visualization: RCR. Writing – original draft: RCR, VJMVC. Writing – review and editing: RCR.

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